COMPARATIVE EVALUATION OF DENTINAL DEFECTS AFTER ROOT CANAL PREPARATION USING VARIOUS NICKEL TITANIUM FILES - AN INVITRO STUDY

Dissertation submitted to

THE TAMIL NADU DR M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the degree of

MASTER OF DENTAL SURGERY

BRANCH - IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

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ENDORSEMENT BY THE H.O.D & PRINCIPAL / THE HEAD OF THE INSTITUTION

This is to certify that **Dr.D.KAMESWARAN,** Post Graduate student (2016–2019) in the Department of Conservative Dentistry and Endodontics, K.S.R. Institute of Dental Science and Research, has done this dissertation titled **"COMPARATIVE EVALUATION OF DENTINAL DEFECTS AFTER ROOT CANAL PREPARATION USING VARIOUS NICKEL TITANIUM FILES-AN INVITRO STUDY"** under our guidance and supervision in partial fulfillment of the regulations laid down by **The Tamil Nadu Dr. M.G.R. Medical University**, Chennai – 600 032 for **M.D.S.,**(Branch – IV) **CONSERVATIVE DENTISTRY AND ENDODONTICS** degree examination.

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TITLE OF DISSERTATION	**Comparative evaluation of dentinal defects after root canal preparation using various nickel titanium files-An invitro study**
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ANNEXURE

APPENDIX III

This is to certify that this dissertation work titled **"COMPARATIVE EVALUATION OF DENTINAL DEFECTS AFTER ROOT CANAL PREPARATION USING VARIOUS NICKEL TITANIUM FILES – AN INVITRO STUDY"** of the candidate **Dr.D.KAMESWARAN** with registration number **241617402** for the award of "**MASTER OF DENTAL SURGERY**" in the branch of **CONSERVATIVE DENTISTRY AND ENDODONTICS**. I personally verified the urkund.com website for the purpose of plagiarism Check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows **9%** percentage of plagiarism in the dissertation.

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INTRODUCTION

The main objective of chemo-mechanical root canal preparation includes the preservation of the original canal anatomy and cleaning of the entire root canal system. Advancements in the rotary nickel titanium instruments have provided better cleaning and shaping with minimal dentinal defects. A dentinal defect such as microcrack is a major concern regarding the prognosis of root canal treated tooth.[1]

One of the most common complications associated with mechanical preparation of root canal is vertical root fractures (VRF) leading to tooth loss. Although there is no clearcut evidence regarding the dentinal defects like microcracks leading to vertical root fracture, the current consensus is that such defects should be prevented.[1]

Wilcox et al found that vertical root fractures may be initiated from a dentinal crack, which can lead to extraction.[2]

Various microscopic studies have reported that there is a causal relationship between dentinal microcracks and instrumentation with rotary as well as reciprocating instruments.[3,4]

A major goal in chemo-mechanical root canal preparation is to overcome the potential problem of dentinal microcrack formation associated with rotary and reciprocation instruments.

Hyflex EDM (Coltene/Whaledent, Altstatten, Switzerland) are the recently introduced continuous rotation single file system made of controlled memory (CM) treatment, which has been proven to increase the flexibility and cyclic fatigue resistance. The EDM is a noncontact machining procedure used in engineering for the manufacturing of parts that would be difficult to machine with conventional techniques. The removal of material is performed by pulsating electric current discharges that flow between an electrode and the workpiece that

are immersed in a dielectric medium. In a well-controlled and repeatable way, the electric current partially melts and evaporates small portions of the material. The material is therefore superficially removed leaving an isotropic surface, characterized by regularly distributed craters. [5]

Although EDM is a common fabrication process for miniaturized components in medical technology, micro-engineering and surgical application, HyFlex EDM are the first endodontic instruments manufactured with the EDM procedure. [6]

HyFlex EDM, mainly composed of martensite and R phase, revealed peculiar structural properties such as increased phase transformation temperatures and higher hardness when compared with HyFlex CM. The different phase composition and the improved hardness may shed light on the enhanced mechanical behaviour of electro-discharge machined instruments.[6] Their design is characterized by a variable cross section ; quadratic at the tip, trapezoidal in the middle and triangular towards the shaft. The Hyflex EDM sequence is as follows: 25/.12 (Orifice Opener), 10/.05 (Glidepath File), 25/~ (OneFile). Hyflex EDM have been claimed to be exceptionally resistant to cyclic fatigue when compared with CM wire or M-Wire files of similar size and taper. [7]

HyFlex EDM NiTi glide path files (Coltene/Whaledent, Altstatten, Switzerland) are the first path file system made of controlled memory (CM) using EDM (electrical discharging machining) technology. HyFlex EDM glide path files have three horizontal cross-sections varying throughout their shaft; quadratic at the tip, trapezoidal in the middle and triangular towards the shaft. HyFlex EDM glide path files consist of a single file having a 0.10 mm tip diameter and 5% taper. [8]

Protaper Next (Dentsply Maillefer, Ballaigues, Switzerland) are the continuous rotary NiTi files made of M-Wire technology (Sportswire LLC, Langley, OK), which yields a microstructure containing portions of martensite, thus enhancing the flexibility and cyclic fatigue resistance of the alloy over conventional NiTi. Protaper Next instruments present a unique off-centered rectangular cross section, except for the apical 3 mm of X1 file where the cross section section is square. The tip sizes are 17/.04, 25/.06, 30/.07, 40/.06, and 50/.06, and the tapers are variable (increasing and then decreasing in the apicocoronal direction for X1 and X2, fixed and then decreasing for X3, X4, and X5). These design features have been studied to enhance flexibility and debris removal, avoid unnecessary dentin removal, and limit taper lock, screw in and torque.[7]

Wave one Gold files are the updated version of Wave One files (Dentsply Maillefer). While maintaining the reciprocation motion of files, their dimensions, cross section, and geometry were altered. The cross section of the file was modified to an alternate offset parallelogram with 2 cutting edges. [9]

This design limits the engagement between the file and dentin to only 1 or 2 points of contact at any given cross-section, subsequently reducing the taper lock and the screw-effect. [10]

The files are manufactured using gold heat treatment. M-Wire technology is based on heat treatment before production. On the contrary, gold heat treatment is performed after production. [9]

Engineers have identified the desired phase-transition point between martensite and austenite that serves to produce a more clinically optimal metal than NiTi itself. The thermal process and post-machining procedure have generated a new supermetal that is commercially termed as Gold-Wire. Specifically, the Primary Wave One Gold file is at least 80% more flexible, 50% more resistant to cyclic fatigue and 23% more efficient compared to its Primary Wave One M-Wire predecessor. [10]

There are 4 Wave One Gold files available in various lengths to more effectively address a wider range of endodontic anatomy compared to its Wave One predecessor. The 4 files are termed *Small* (yellow 20/07), *Primary* (red 25/07), *Medium* (green 35/06), and *Large* (white 45/05). Each file has a fixed taper from D1-D3, yet a progressively decreasing percentage tapered design from D4-D16, which serves to preserve dentin. For example, the Primary file has diameters of 0.85 mm and 1.0 mm at D9 and D12 respectively or the length of this file typically extends below the orifice during canal preparation. The Primary 25/07 file is the only file required to shape any given canal completely.[10]

ProGlider (Dentsply Maillefer, Ballaigues, Switzerland) NiTi rotary glide path file is made of M-wire alloy. ProGlider has 0.16-mm tip diameter and variable taper between 2% and 8% along the shaft. Variable taper design allows coronal pre-expansion for the use of next larger files. The file is manufactured in lengths of 21, 25 and 31 mm and has square cross section.[11]

AIM

- To evaluate the incidence of dentinal defects after root canal preparation using various nickel titanium files.

OBJECTIVES

- To compare the dentinal defects after using Hyflex EDM, ProTaper Next and Waveone Gold Nickel titanium files.

Souza Bier et al (2009) compared the incidence of dentinal defects (fractures and craze lines) after canal preparation with different nickel-titanium rotary files. Two hundred sixty mandibular premolars were selected. Forty teeth were left unprepared (n = 40). The other teeth were prepared either with manual Flexofiles (n = 20) or with different rotary files systems: ProTaper (Dentsply-Maillefer, Ballaigues, Switzerland), ProFile (Dentsply-Maillefer), SystemGT (Dentsply-Maillefer), or S-ApeX (FKG Dentaire, La Chaux-de-Fonds, Switzerland) (n = 50 each). Roots were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex and observed under a microscope. Results of this study showed that the use of some rotary NiTi instruments could result in an increased chance for dentinal defects.[12]

Shemesh et al (2009) evaluated the incidence of defects in root dentin before and after root canal preparation and filling. Eighty extracted mandibular premolars were divided equally into four groups. Group 1 was left unprepared and served as control. All other root canals were instrumented using Gates Glidden drills and System GT files up to size- 40, 0.06 taper at the working length. Group 2 was left unfilled while the canals of the other groups were filled with gutta-percha and AH26, either with a master cone and passive insertion of secondary gutta percha points (group 3) or lateral compaction (group 4). Roots were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex and observed through a microscope. Canal preparation alone caused significantly more defects than unprepared canals. The total number of defects after lateral compaction was significantly higher than after noncompaction canal filling. Results showed that root canal preparation and filling of extracted teeth created dentine defects such as fractures, craze lines and incomplete cracks.[13]

Shemesh et al (2010) conducted a study in extracted teeth to compare the incidence of dentinal defects (cracks and craze lines) after root canal preparation, lateral compaction, continuous wave compaction of gutta-percha and AH26 sealer. Two hundred mandibular premolar teeth were selected and divided into four groups with similar average canal diameters (n = 50). One group was left untreated and served as control. The other three groups were instrumented with ProTaper rotary instruments upto size F4. After preparation, one group was not filled while two groups were filled with gutta-percha and AH26 using either lateral compaction or the continuous wave technique. Roots were then sectioned perpendicular to the long axis at 3, 6 and 9 mm from the apex and inspected under a microscope. Results showed that both lateral compaction and the continuous wave filling techniques had a damaging effect on the root canal wall. Filling methods should be assessed not only for their ability to seal the canal but also for the potential damage they might cause to the root.[14]

Adorno et al (2010) evaluated the effects of working length and root canal preparation technique on crack development in the apical root canal wall. Seventy extracted mandibular premolars were mounted in a resin block and then divided into seven groups according to preparation technique and working length: group A, step-back preparation using stainless steel files with working length set at the apical foramen was defined as root canal length (CL); group B, same as for A, except that the working length was CL minus 1 mm; group C, crown-down preparation with Profile instruments followed by an apical enlargement sequence with CL as working length and group D, same as for C, except that the working length was CL minus 1 mm. Groups E, F and G served as controls. Groups E and F were instrumented only with the crown-down sequence up to CL and CL minus 1 mm, respectively. Group G was left unprepared. Digital images of the apical root surface (AS)

were recorded before preparation, immediately after instrumentation and after removing the apical 1 mm (AS minus 1 mm) and 2 mm (AS minus 2 mm) of the root end. Results of this study showed that root canal preparation alone, can potentially generate cracks on the apical root canal wall as well as the apical surface, regardless of the technique used. Working length 1 mm short of the apical foramen might produce lesser cracks in the apical region.[15]

Kim et al (2010) compared the stress conditions during rotary instrumentation in a curved root for three NiTi file designs. These design variations may also alter the forces on a root during instrumentation and cause dentinal defects that predispose a root to fracture. Finite element (FE) analysis is used to calculate the stresses and FE models of ProFile (Dentsply Maillefer, Ballaigues, Switzerland; U-shaped cross-section and constant 6% tapered shaft), ProTaper Universal (Dentsply; progressive taper shaft and convex triangular cross-section with notch), and LightSpeed LSX (Lightspeed Technology Inc, San Antonio TX; noncutting round shaft) were rotated within a curved root canal. The stress and strain conditions resulting from the simulated shaping action were assessed in the apical root dentin. Results of the study showed that the stiffer file designs caused higher stress concentrations in the apical root dentin during shaping of the curved canal, which increases the risk of dentinal defects that may lead to apical root cracking. Thus, stress levels during shaping and fracture susceptibility after shaping may vary with instrument design.[16]

Adorno et al (2011) conducted a study to compare the effects of three brands of nickel-titanium (NiTi) rotary files with different designs on the development of apical root cracks when working short, at, and beyond the apical foramen. One-hundred eight teeth with straight single canals were selected and then mounted on resin blocks and the apex was exposed. The teeth were divided into 9 groups according to the NiTi rotary file type used (Profile [Dentsply

Maillefer, Ballaigues, Switzerland], K3 [SybronEndo, West Collins, CA], and EndoWave [FKG Dentaire, La-Chaux-de-Fonds, Switzerland]) and working length (at CL, 1 mm short of [CL minus 1 mm], and 1 mm beyond [CL plus 1 mm] the apical foramen). Digital images of the apical surface were recorded during the apical enlargement sequence at each file change. These images were compared with the baseline image, and the presence of a crack was evaluated. Results of this study showed that working 1 mm short of the apical foramen caused less cracks on the apical surface and, more cracks were observed when using larger file sizes. Instrumentation with NiTi rotary files could potentially induce cracks on the apical root surface.[17]

Yoldas et al (2012) conducted a study to compare dentinal microcrack formation while using hand files (HFs), 4 brands of nickel-titanium (NiTi) rotary files and the self-adjusting file. One hundred forty mandibular first molars were selected. Twenty teeth were left unprepared and remaining 120 teeth were divided into 6 groups. Hand files (HFs), HERO Shaper (HS; Micro-Mega, Besancon, France), Revo-S (RS, Micro-Mega), Twisted File (TF; SybronEndo, Orange, CA), ProTaper (PT, Dentsply Maillefer), and Self adjusting files (SAFs) were used to instrument the 2 mesial canals. Roots were then sectioned at 3, 6, and 9 mm from the apex, and the cut surface was observed under a microscope and assessed for the presence of dentinal microcracks. All rotary files caused microcracks in the root dentin, whereas the SAF file and hand instrumentation showed with satisfactory results with no dentinal microcracks.[18]

Al zaka et al (2012) conducted a study to compare dentinal defect formation while using hand files (HFs), two brands of nickel-titanium (NiTi) rotary files and the WaveOne file. Eighty mandibular first molars were selected. All teeth were divided into 4 groups. Hand file (HFs), WaveOne reciprocating file (WO), EndoSequence file (ES), ProTaper file (PT), were

used to instrument the 2 mesial canals. Roots were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex, and the cut surface was observed under a microscope and evaluated for the presence of dentinal defects. Hand Files group showed fewer dentinal defects (5%). In roots prepared with the WO, ES, and PT, dentinal defects were observed in 25%, 10%, and 50% of teeth, respectively. There was a significant difference between HFs group and both of WO group and PT group ($P < 0.05$). However, there was no significant difference found between HFs group and ES group ($P \geq 0.05$). Also a non significant difference was seen between WO group and ES group ($P \geq 0.05$). Results of this study showed that all rotary files caused defects in the root dentin, whereas hand instrumentation presented with satisfactory results.[19]

Baretto et al (2012) conducted a study to evaluate the ex vivo effects of root canal preparation, filling techniques, and mechanical cycling (MC) on the incidence of dentin defects and vertical root fractures (VRFs). Seventy extracted single-rooted teeth were selected and divided into 6 groups. The first 2 groups were left unprepared and unprepared/MC groups. The other groups were instrumented by using Gates Glidden drills and ProTaper Universal files up to F3 and were divided according to the following: prepared teeth and without root canal filling, passive technique, lateral compaction, and Tagger's hybrid technique. All of the groups except the unprepared group were subjected to MC(1,000,000 cycles, 90 N, 4 Hz, 37_C). The roots were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex and observed under a 10x stereomicroscope. Results of this study showed that MC by itself did not cause VRF. When associated with apical pressure filling techniques, however, VRF occurred in 13.3% (lateral compaction) and 33.3% (Tagger's hybrid) of the cases.[20]

Liu et al (2013) compared the incidence of apical root cracks and dentinal detachments after canal preparation with hand and rotary files at different instrumentation lengths. Two hundred forty mandibular incisors were mounted in resin blocks and the apex was exposed. The root canals were instrumented with rotary and hand files, K3, ProTaper, and nickel-titanium Flex K files to the major apical foramen (AF), short of AF, or beyond AF. During apical enlargement, digital images of the apical surface of every tooth were taken at each file change. Development of dentinal defects was analyzed by comparing these images with the baseline image. Results of this study showed that rotary instruments caused more dentinal defects than hand instruments and the instrumentation short of apical foramen reduced the risk of dentinal defects.[21]

Adorno et al (2013) conducted a study to evaluate the potential effects of endodontic procedures (instrumentation and filling) on crack initiation and propagation in apical dentine. Forty extracted single-rooted premolars with two canals were selected and 1.5 mm of the apex was ground horizontally and the surface polished. The specimens were then divided into 4 groups. The buccal canals of groups A, B and C were prepared up to size 40 with manual K-files. Group A was obturated with gutta-percha using lateral condensation and vertical compaction without sealer. Group B was obturated with the same method as group A except only lateral condensation was used. Group C was not obturated, while group D was left unprepared and unfilled. Digital images of the resected surface were taken after resection (baseline), canal preparation, filling and 4-week storage. The images were then evaluated for cracks originating from the canal. Results of this study showed that root canal procedures can potentially initiate and propagate cracks from within the root canal in the apical region.[22]

Abou El Nasr and Abd El Kadar et al (2014) conducted a study to determine the effect of instrumentation kinematics and the material of instrument construction of single-file systems on dentin walls and fracture resistance of oval roots. Sixty-five roots with oval canals were selected and five teeth served as a control group and 3 experimental groups of 20 roots each. Group WO was prepared using Wave One primary file (Dentsply Maillefer, Baillagues, Switzerland), group PT-Rec was instrumented with F2 ProTaper files (Dentsply Maillefer, Baillagues, Switzerland) used in a reciprocating motion, and group PT-Rot was instrumented with F2 ProTaper files used in a rotation motion. For crack evaluation, half of the samples (n = 30) were embedded in acrylic resin, and the blocks were sectioned horizontally at 3, 6, and 9 mm from the apex. The sections were observed under a stereomicroscope and checked for crack presence.The other half of the specimens (n = 30) were filled using lateral condensation of gutta-percha and AdSeal sealer (Meta Biomed Co, Ltd, Chungbuk, Korea). The specimens were then subjected to a load of 1 mm/min to evaluate the force required to fracture the roots. Results of this study showed that the alloy from which the material is manufactured is a more important factor determining the dentin damaging potential of single-file instruments than the motion of instrumentation.[23]

Ashwin kumar et al (2014) conducted a study to compare dentinal microcrack formation whilst using Ni–Ti hand K-files, ProTaper hand and rotary files and the WaveOne reciprocating file. One hundred fifty mandibular first molars were selected. Thirty teeth were left unprepared and the remaining 120 teeth were divided into four groups. Ni–Ti hand K-files, ProTaper hand files, ProTaper rotary files and WaveOne Primary reciprocating files were used to enlarge the mesial canals. Roots were then sectioned perpendicular to the long axis at 3, 6 and 9 mm from the apex, and the cut surface was observed under scanning

electron microscope (SEM) and assessed for the presence of dentinal microcracks. Results of this study showed that ProTaper rotary files were associated with significantly more microcracks than ProTaper hand files and WaveOne Primary reciprocating files. Ni–Ti hand K-files did not cause microcracks at any levels inside the root canals.[4]

Capar et al (2014) conducted a study to investigate the incidence of cracks in root dentin after root canal preparation with ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland), HyFlex (Coltene- Whaledent, Allstetten, Switzerland), and ProTaper Universal (Dentsply Maillefer) rotary instruments. One-hundred mandibular premolars were selected. Twenty-five teeth were left unprepared and served as a negative control; another 25 teeth were prepared with the ProTaper Universal system up to size F4 as a positive control, and the remaining 50 teeth were prepared with the following experimental groups with an apical size 40 file: ProTaper Next X4 and HyFlex 40/0.4. After root canal preparation, all of the roots were sectioned horizontally at 2, 4, 6, and 8 mm from the apex, and the sections were then observed under a stereomicroscope. Results of this study showed that all of the instrumentation systems used in this study caused cracks in the root dentin. The ProTaper Next and HyFlex instruments tended to cause lesser dentinal cracks compared with the ProTaper Universal instrument.[24]

Topcuoglu et al (2014) conducted a study to compare the incidence of dentinal defects after retreatment procedures with different nickel-titanium rotary retreatment files. One hundred-eighty mandibular premolars were divided to 6 groups (n = 30 teeth per group). One group was left unprepared, and the remaining 5 groups were instrumented with K-files (Dentsply Maillefer, Ballaigues, Switzerland) and obturated with gutta-percha and AH plus sealer (Dentsply Maillefer, Ballaigues, Switzerland). Of these 5 groups, 1 group was left obturated

and received no further treatments; in the other groups, removal of the filling material was done using Mtwo R (VDW, Munich, Germany), D-RaCe (FKG Dentaire, La Chaux-de-Fonds, Switzerland), REndo instruments (Micro-Mega, Besanc¸on, France), or Hedstr€om files (Dentsply Maillefer). Roots were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex and observed under a microscope. Results of this study showed that all retreatment techniques created defects in the root dentin.[25]

Arias et al (2014) conducted a study in a cadaver model was to compare 2 different shaping techniques regarding the induction of dentinal microcracks. Three lower incisors from each of 6 adult human cadaver skulls were divided into 3 groups: the control group (CG, no instrumentation), the GT group (GT Profile hand files; Dentsply Tulsa, Tulsa, OK), and the WO group (WaveOne; Dentsply Tulsa Dental). In the GT group, manual shaping in a crowndown sequence using GT Profile hand files was performed. In the WO group, Primary WaveOne files were used till working length. Teeth were removed from the mandibles by careful removal of soft tissue and bone under magnification. Roots were then sectioned horizontally at 3, 6, and 9 mm from the apex using a low-speed saw. Color photographs at 2magnifications (25x and 40x) were taken. Three blinded examiners assessed the presence of microcracks (yes/no), extension (incomplete/complete), direction (buccolingual/mesiodistal), and location. Results of this study showed that the relationship between the shaping techniques (GT hand and WaveOne) and the incidence of microcracks could not be shown compared with uninstrumented controls.[26]

De-Deus et al (2014) conducted a study to evaluate the frequency of dentinal microcracks observed after root canal preparation with 2 reciprocating and a conventional full sequence rotary system using micro–computed tomography. Thirty mesial roots of mandibular molars

were selected. The sample was randomly divided to 3 experimental groups (n = 10) according to the system used for the root canal preparation: group A—Reciproc (VDW, Munich, Germany), group B—WaveOne (Dentsply Maillefer, Baillagues, Switzerland), and group C—BioRaCe (FKG Dentaire, Switzerland). Second and third scans were performed after the root canals were enlarged with instruments sizes 25 and 40, respectively. Then, pre- and postoperative cross-section images of the roots (N = 65,340) were screened to check the presence of dentinal defects. Results of this study showed that there is no causal relationship between dentinal microcrack formation and canal preparation procedures with Reciproc, WaveOne, and BioRaCe systems.[27]

Kansal et al (2014) conducted a study to compare the formation of dentinal cracks with instruments working in continuous rotation and reciprocating motion. One hundred twenty extracted human mandibular premolars were selected. Thirty teeth served as controls, and the remaining 90 teeth were divided into 3 groups according to the root canal preparation technique. Group 1 samples were prepared with WaveOne primary files (Dentsply Maillefer, Ballaigues, Switzerland), group 2 samples with single F2 ProTaper (Dentsply Maillefer) working in reciprocating motion, and group 3 samples were treated with ProTaper (Dentsply Maillefer) until F2 working in continuous rotation motion. Roots were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex, and the cut surface was observed under a stereomicroscope to check the presence of dentinal microcracks. Dentinal cracks are produced irrespective of motion kinematics. Results of this study showed that such incidence is less with instruments working in reciprocating motion compared with those working in continuous rotation.[28]

Ustun et al (2015) compared the incidence of dentinal defects caused by reciprocating and rotary techniques during retreatment procedures. One hundred and twenty mandibular premolars with single canals were selected. Twenty teeth were left unprepared and served as control. The root canals in the remaining teeth were prepared with K-files up to size 35 and filled with gutta-percha and AH Plus sealer using a passive cold lateral compaction technique. Twenty canals were filled and undergoes no further treatment. Eighty teeth were divided into four groups (n = 20 in each) to remove the root filling. In groups 1 and 2, the root filling was removed using ProTaper Retreatment files and Reciproc files, respectively, and the canals were not refilled. In groups 3 and 4, the root filling was removed using ProTaper Retreatment files and Reciproc files, respectively, and the canals were then re-filled using a conventional cold lateral compaction technique. The roots were sectioned perpendicular to the long axis at 3, 6, and 9 mm from the root apex and observed under a stereomicroscope at 20x magnification. Results of this study showed that NiTi systems, both with reciprocating and rotational movement have tendency to induce dentinal defects during retreatment procedures. Additionally, the Reciproc system was associated with significantly higher number of cracks in the middle and coronal part of the roots than the ProTaper system.[29]

Jamleh et al (2015) conducted a study to determine the root surface strain (RSS) generated during root canal shaping and its effects on apical microcrack development. Twenty-five extracted human mandibular premolars were selected and instrumented with either the ProTaper (PT) or WaveOne (WO) (Dentsply Maillefer) NiTi rotary systems (n=10 per group) or used as controls (n=5). Instrumented root canals were prepared to ProTaper F4 (size 40, 0.06 taper) or using WaveOne LARGE (size 40, 0.08 taper) instruments according to the

manufacturer's instructions. An electrical strain gauge (KFG02-120-C1-16, Kyowa Dengyo, Tokyo, Japan) was fixed on the proximal root surface and connected to a strain amplifier via a bridge-box in order to evaluate RSS. During canal shaping, the strain output of the amplifier was evaluated. The instantaneous RSS induced by each instrument and the maximum RSSs were evaluated. All teeth were then stained using contrast media and observed using micro-computed tomography (micro-CT) at an isotropic resolution of 10 μm to evaluate microcracks. Results of this study showed that canal shaping appears to cause apical microcracks regardless of the type of rotary instrument motion. Contrast-enhanced micro-CT was able to detect microcracks in roots.[30]

Cicek et al (2015) conduced a study to evaluate the dentinal microcrack formation of ProTaper Universal, ProTaper Next, and WaveOne. Sixty extracted mandibular molars were selected. The mesial roots were resected and divided into four groups (n.15). The canals were enlarged with hand files (group 1), ProTaper Universal (group 2), ProTaper Next (group 3), and WaveOne (group 4) instrument systems. The roots were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex. Digital images were taken at x40 magnification using scanning electron microscope to detect microcrack formation. The prevalence of microcracks in group 2, group 3, and group 4 were significantly higher when compared to group 1 ($p<0.001$). Group 2, group 3, and group 4 demonstrated similar prevalence of microcracks without significant difference ($p>0.05$) in all sections. Results of this study showed that all instruments caused microcracks except for hand file. The highest percentage of microcrack was recorded in 3mm section for all groups.[31]

Shori et al (2015) conducted a study to evaluate dentinal defects formed by Protaper next (PTN) rotary system. Sixty single-rooted premolars were selected. All specimens were decoronated and divided into four groups (n=15). Group I specimens were prepared by using Hand K-files (Mani), Group II with ProTaper Universal (PT; Dentsply Maillefer), Group III with Hero Shaper (HS; Micro-Mega, Besancon, France), and Group IV with PTN (Dentsply Maillefer). Roots of each specimen were sectioned horizontally at 3, 6, and 9 mm from the apex and were then observed under a stereomicroscope to check the presence or absence of dentinal defects. Results of this study showed that all rotary files induced defects in root dentin, whereas the hand instruments induced minimal defects.[32]

Aktemur Turker S et al (2015) conducted a study to evaluate dentinal crack formation after root canal preparation with ProTaper Next system (PTN) with and without a glide path. Forty-five mesial roots of mandibular first molars were selected. Fifteen teeth were left unprepared and served as control. The experimental groups consist of mesiobuccal and mesiolingual root canals of remaining 30 teeth were divided into 2 groups (n = 15): Group PG/PTN, glide path was done by using ProGlider (PG) and canals were shaped with PTN system; Group PTN, glide path was not prepared and canals were shaped with PTN system only. All roots were then sectioned perpendicular to the long axis at 1, 2, 3, 4, 6, and 8 mm from the apex, and the sections were seen under a stereomicroscope. Results of this study showed that the creation of the glide path before ProTaper Next rotary system did not influence dentinal crack formation in root canals.[33]

Zhou et al (2015) conducted a study to compare dentinal and apical crack formation after instrumentation with different nickel-titanium systems at two different working lengths (WL) in large and small canals. Two hundred and eighty human teeth were selected and divided into two control and 12 experimental groups (*n*=20 each). Large and small canals were prepared by using the WaveOne, Protaper Universal System (PTU), Twisted File (TF), or Twisted File Adaptive (TFA) at 1 mm shorter than canal length (CL minus 1 mm) or 1 mm beyond apical foreman (CL plus 1 mm). Horizontal sections were microscopically observed to check the dentinal cracks (only large canals). Scanning electron microscopy images were taken before and after instrumentation to evaluate apical cracks. All file types produced more apical cracks in small canals than in large canals regardless of the working length (WL). Results of this study showed that during over-instrumentation (WL=CL plus 1 mm), the WaveOne and PTU groups caused significantly higher number of dentinal cracks at the 6 and 9 mm sections than the TF and TFA groups.[34]

Rose et al (2015) conducted a study to evaluate dentinal cracks in non extracted teeth after final instrumentation. Mandibular first and second premolars of pig jaws were selected. Forty single-rooted canals were divided into 5 groups (n = 8): (1) WaveOne (Dentsply Tulsa Dental Specialties, Tulsa, OK) 25/08; (2) ProTaper rotary S1, S2, F2 (25/08) (Dentsply Tulsa Dental Specialties); (3) crown-down GT hand files 20/12, 20/10, 20/08 (Dentsply Tulsa Dental Specialties); (4) positive control (purposefully cracked); and (5) negative control (uninstrumented teeth). After instrumentation superficial soft tissue was removed and bone was carefully removed using surgical burs to the level of the root apices. Roots were resected 1 mm coronal to the working length, stained with caries indicator dye, and transilluminated; images were captured at 30x magnification to evaluate the presence or absence of dentinal cracks. Results of this study showed that the presence of natural periodontal structures may

prevent cracking or dentinal damage in teeth undergoing orthograde root canal instrumentation.[35]

Adl et al (2015) conducted a study to evaluate the effect of using RC Prep (Well-Prep, Vericom Co, Anyang, Korea) during root canal preparation on the incidence of defects in root canal walls. One hundred extracted mandibular incisors with single canals were selected. Teeth were then divided into one control group and four experimental groups (n = 20). The teeth in group 1 (control) were coronally flared with Gates Glidden drills (Mani, Japan), but received no further preparation. All teeth in the experimental groups were first coronally flared with Gates Glidden drills and then enlarged by means of ProTaper instruments (Dentsply Maillefer, Ballaigues, Switzerland). The difference between the experimental groups was the following: in group 2, saline was used as an irrigation solution without application of RC Prep; in group 3, teeth were irrigated with saline, and RC Prep was also used to canals before the insertion of each file; in group 4, sodium hypochlorite (NaOCl) was used for irrigation without the application of RC Prep; and in group 5, both NaOCl and RC Prep were used. The apical root surface and horizontal sections at 3, 6, and 9 mm from the apex were evaluated under a microscope. Results of this study showed that RC Prep was unable to reduce the risk of dentinal defects. NaOCl caused more defects compared with saline.[36]

Li et al(2015) conducted a study to compare the incidence of dentinal microcracks produced by the ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland), WaveOne (Dentsply Maillefer), and ProTaper Next (Dentsply Maillefer) file systems during root canal procedures in severely curved canals using a dyeing technique. Sixty extracted human molars with 25˚ to 40˚ root curvatures were selected and divided into 3 groups of 20 canals each.

ProTaper Universal, WaveOne, and ProTaper Next file systems were used for canal shaping procedures. Untreated root canals of 60 molars served as negative controls. After preparation, all roots were stained with 1% methylene blue for 24 hours. Roots were then sectioned at the most curved plane and 2 mm above and below the most curved plane with a low-speed saw under cold water. A stereomicroscope was used to evaluate dentinal microcracks at 60x magnification. Results of this study showed that ProTaper Next system induces less dentinal microcracks during root canal procedures in severely curved root canals when compared with the ProTaper Universal and WaveOne systems.[37]

Karatas et al (2016) conducted a study to evaluate the effect of root canal preparation using ProTaper Gold, Profile Vortex, F360, Reciproc and ProTaper Universal instruments on dentinal crack formation. Ninety mandibular central incisor teeth with straight canals (<5°) were selected and stored in distilled water. Fifteen teeth were left unprepared, served as control and the remaining 75 teeth were divided into five root canal shaping groups (n = 15): ProTaper Gold, Pro-File Vortex, F360, Reciproc and ProTaper Universal. All the roots were sectioned perpendicular to the long axis at 3, 6 and 9 mm from the apex with a lowspeed saw under water cooling. The samples were then observed through a stereomicroscope at 25x magnification. The presence of dentinal cracks was evaluated by photographing all samples using a digital camera. Results of this study showed that PTU group was associated with more dentinal crack formation than PTG, PV, F360 and Reciproc groups at the 3 mm level.[38]

Coelho et al (2016) conducted a study to evaluate the presence of dentinal defects after root canal preparation in extracted human teeth by using the root sectioning methodology to assess whether light-emitting diode (LED) trans illumination enhances the visualization of dentinal defects by using a root sectioning methodology. Forty mesial roots of mandibular

molars were selected and sectioned at 3, 6, and 9 mm from the apex with a low-speed saw under water cooling. Microscopic pictures of the specimens were taken by using 19.2x magnification for the 3-mm slice; 12.8x magnification for the 6- and 9-mm slices. LED transillumination was done by positioning an LED probe at 4 different areas (mesial, distal, buccal, and lingual). The root canal lumen was masked, and 2 independent observers assessed the presence of dentinal defects on the non-LED and LED images. They found that LED transillumination enhanced the visualization of dentinal defects in un instrumented roots.[39]

Dane et al (2016) conducted a study to observe the incidence of cracks in root canal dentin using the ProTaper Universal system (Dentsply Maillefer, Ballaigues, Switzerland) at low- and high-torque settings. Sixty-nine mandibular premolar teeth were selected. The teeth were divided into 3 groups: an unprepared control group, a low-torque settings group (SX = 3, S1 = 2, S2 = 1, F1 = 1.5, F2 = 2, F3 = 2, F4 = 2 N/cm), and a high-torque settings group (SX = 4, S1 = 4, S2 = 1.5, F1 = 2, F2 = 3, F3 = 3, F4 = 3 N/cm). After a root canal procedure, all the teeth were sectioned perpendicular to the long axis at 2, 4, 6, and 8 mm from the apex. Then, under a stereomicroscope, all the slices were evaluated to check the presence of cracks. Results of this study showed that the instrumentation of root canals with the ProTaper Universal instrument caused more crack formation in root canal dentin at high-torque than at low-torque settings.[40]

Ashraf et al (2016) evaluated the dentinal cracks after root canal preparation with rotary files: Gates Glidden, ProTaper Universal, ProTaper Next, and HyFlex CM at different instrumentation lengths. Sixty-five mandibular premolars were mounted in the acrylic tube and the apex was exposed. The root canals were instrumented with different rotary files,

ProTaper Universal, ProTaper Next, and HyFlex CM, to the major apical foramen (AF), short AF, and beyond AF. The root apex was stained with 1% methylene blue dye and digital images of the apical surface of every tooth were taken and development of dentinal defects was analysed using stereomicroscope. Results showed that ProTaper Next and HyFlex CM rotary files caused fewer dentinal cracks when compared with ProTaper Universal file system which showed the highest number of dentinal cracks.[41]

Amaral et al (2016) conducted a study to evaluate the prevalence of dentin defects, including partial and complete cracks and fractures, after root canal preparation in molars with Reciproc and WaveOne reciprocating instruments. Fifty mandibular first and second molars were selected. Ten teeth were left unprepared and the remaining forty teeth were divided into two groups. Reciproc and WaveOne systems were used in a reciprocating motion to prepare the two mesial canals. Roots were then sectioned perpendicular to the long axis at 2, 4 and 6 mm from the apex, and observed under a microscope using 20-fold magnification. Results of this study showed that Reciproc and WaveOne systems created incomplete cracks in the root dentin, but not in fractures. Wave One caused lesser structural alterations on dentin considering the middle portion of the roots when compared with Reciproc system.[42]

Pedulla et al (2016) conducted a study to compare the formation of microcracks after canal preparation with different single-file systems as One Shape (Micro-Mega, Besancon, Cedex, France), F6 SkyTaper (Komet Italia Srl, Milan, Italy), HyFlex EDM (Coltene/Whaledent AG, Altstatten, Switzerland), WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), Reciproc (VDW, Munich, Germany), and WaveOne Gold (Dentsply Maillefer). Eighty-four human extracted mandibular central incisors were selected. Twelve teeth were left unprepared(Control) and the remaining seventy two teeth were divided into 6 experimental

groups (n = 12 teeth): One Shape (group 1), F6 SkyTaper (group 2), HyFlex EDM (group 3), WaveOne (group 4), Reciproc (group 5), and WaveOne Gold (group 6). Roots were then sectioned perpendicular to the long axis at 3, 6, and 9 mm from the apex, and the surface was observed under a stereomicroscope. All the instruments tested created dentinal cracks. The flexibility of nickel-titanium instruments seems to have a significant influence on dentinal crack formation. Hy-Flex EDM and WaveOne Gold caused less microcracks than the other instruments tested in this study.[43]

Ceyhanli et al (2016) conducted a study to evaluate ex vivo the incidence of microcracks in root dentine after canal preparation with ProTaper Universal (PTU), RaCe or Safesider instrumentation systems using microcomputed tomography (micro- CT). Thirty freshly extracted mandibular molars with two separate mesial canals were selected. The roots were divided into three groups according to curvature angles and radii of the canals and lengths of the roots. Distal roots were removed and mesial roots were embedded in acrylic resin and then the canals were shaped with the PTU, RaCe or Safesider systems up to size 30 (F3 for PTU, size 30, 0.04 taper for RaCe and Safesider) for all instrumentation groups. Dentinal microcracks were inspected on micro-CT images of the apical 10 mm of the roots with 1-mm intervals. Results of this study showed that all instrumentation systems significantly increased the number of microcracks compared with preoperative specimens. The PTU system generated more post-instrumentation dentinal microcracks than the RaCe system.[44]

Wei et al (2017) conducted a meta-analysis to compare the influence of two types of nickel titanium (NiTi) instruments that have different movements (reciprocating single-file versus full-sequence rotary file systems) on dentinal cracks formation during root canal preparation. A meta-analysis was conducted using Review Manager 5.3 software. The results showed that

the WaveOne and Reciproc files with a reciprocating motion caused significantly fewer dentinal cracks than the conventional rotational ProTaper technique.[45]

Cassimiro et al (2017) conducted a study to evaluate the frequency of dentinal defects after root canal preparation with the ProTaper NEXT, K3XF and WaveOne GOLD systems using microcomputed tomography. Sixty permanent mandibular incisors were selected. Inspection of the teeth was performed under a stereomicroscope (15x) to evaluate the presence of pre-existing cracks and fractures lines. Samples were divided into three groups (n = 20): ProTaper NEXT (PTN), K3XF (K3XF) and WaveOne GOLD (WOG). Specimens were inspected through high-resolution microcomputed tomography before and after the preparation of the root canal. Results of this study showed that there was no correlation between the preparation of a root canal using the PTN, K3XF and WOG systems and the formation of new dentinal defects.[46]

Bayram et al (2017) conducted a study to evaluate the frequency of dentinal microcracks observed after root canal preparation with HyFlex CM (Coltene/ Whaledent, Altstєatten, Switzerland), HyFlex EDM (Coltene/Whaledent), Vortex Blue (Dentsply, Tulsa Dental Specialties, Tulsa, OK), and TRUShape (Dentsply, Tulsa Dental Specialties) systems using micro–computed tomographic (micro-CT) analysis. Forty human mandibular incisors with single and straight root canals were selected into five groups(n = 10) and one group was served as control group and for root canal preparation: group 1, HyFlex CM; group 2, HyFlex EDM; group 3, Vortex Blue; and group 4, TRUShape. The specimens were scanned using a high-resolution micro-CT imaging before and after root canal preparation.Afterward, preoperative and postoperative cross-sectional images of the teeth were evaluated to check the presence of dentinal defects. Results of this study showed that root canal preparation with

the HyFlex CM, HyFlex EDM, Vortex Blue, and TRU Shape systems did not cause the formation of new dentinal microcracks on straight root canals of mandibular incisors.[47]

Rodig et al (2018) conducted a study to evaluate the effect of moisture content in root canal dentine on detection of microcracks using micro-computed tomography. Ten roots with and without craze lines or cracks (n = 5) were selected. Roots were then scanned six times with different moisture conditions of root dentine using micro-CT scanner at a high resolution of 10.5 μm. Scanning conditions were as follows: 1. after 30 days wet storage, 2. after 2 hours dry time, 3. after 48 hours wet storage, 4. after 24 hours dry time, 5. after 48 hours wet storage, 6. after 2 hours dry time. From each scan, cross-sectional images were obtained at intervals of 1 mm (total n = 708) and checked for the presence of dentinal microcracks twice by five blinded observers. Results of this showed that the moisture content of dentine influenced detection of microcracks when inspected using micro-CT. Scanning should be carried out on dried specimens to allow reliable identification of dentinal defects. Formation of new cracks during dry periods up to 24 hours was disproved.[48]

MATERIALS AND METHODS

The following were used:

(1) Sixty extracted human mandibular first premolar.

(2) Rotary files:

- **ProTaper Next** (Dentsply Malleifer, Ballaigus, Switzerland),
- **Waveone Gold** (Dentsply Malleifer, Ballaigus, Switzerland), and
- **HyFlex EDM** (Coltene Whaledent, Altstetten, Switzerland).
- **Proglider** (Dentsply Malleifer, Ballaigus, Switzerland).

(3) K-file number #10.

(4) Acrylic resin.

(5) Polyvinyl siloxane impression material.

(6) Endo motor X-smart Plus (Dentsply Malleifer, Ballaigus, Switzerland).

(7) 30 gauge needle and syringe (5 ml, Prima Dental Irrigation Needle).

(8) 5.25% Sodium hypochlorite.

(9) 17% EDTA.

(10) Normal Saline.

(11) Hard tissue microtome (Leica SP 1200).

(12) Stereomicroscope.

(13) Camera.

Sixty mandibular first premolars were selected and stored in purified filtered water. The coronal portions were removed by using a diamond disc, leaving roots of approximately 16 mm in length. All roots were inspected with stereomicroscope under 12X magnification to detect any pre-existing craze lines or cracks. Teeth with such findings were excluded from the study. A polyvinyl siloxane impression material was used to coat the cemental surface of roots for simulating periodontal ligament space. Then, all the roots were embedded in acrylic blocks. Canal patency was established with a #10 K-File. Sixty teeth were divided into 4 experimental groups (n=15) according to the instrument system that used for preparation.

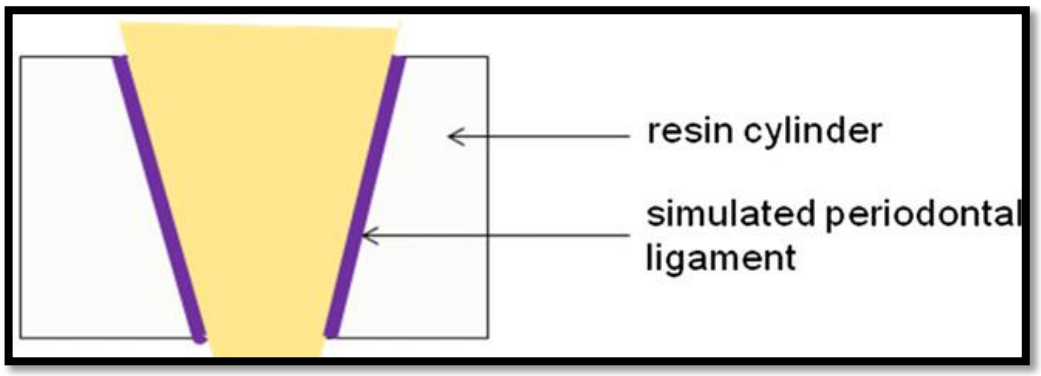
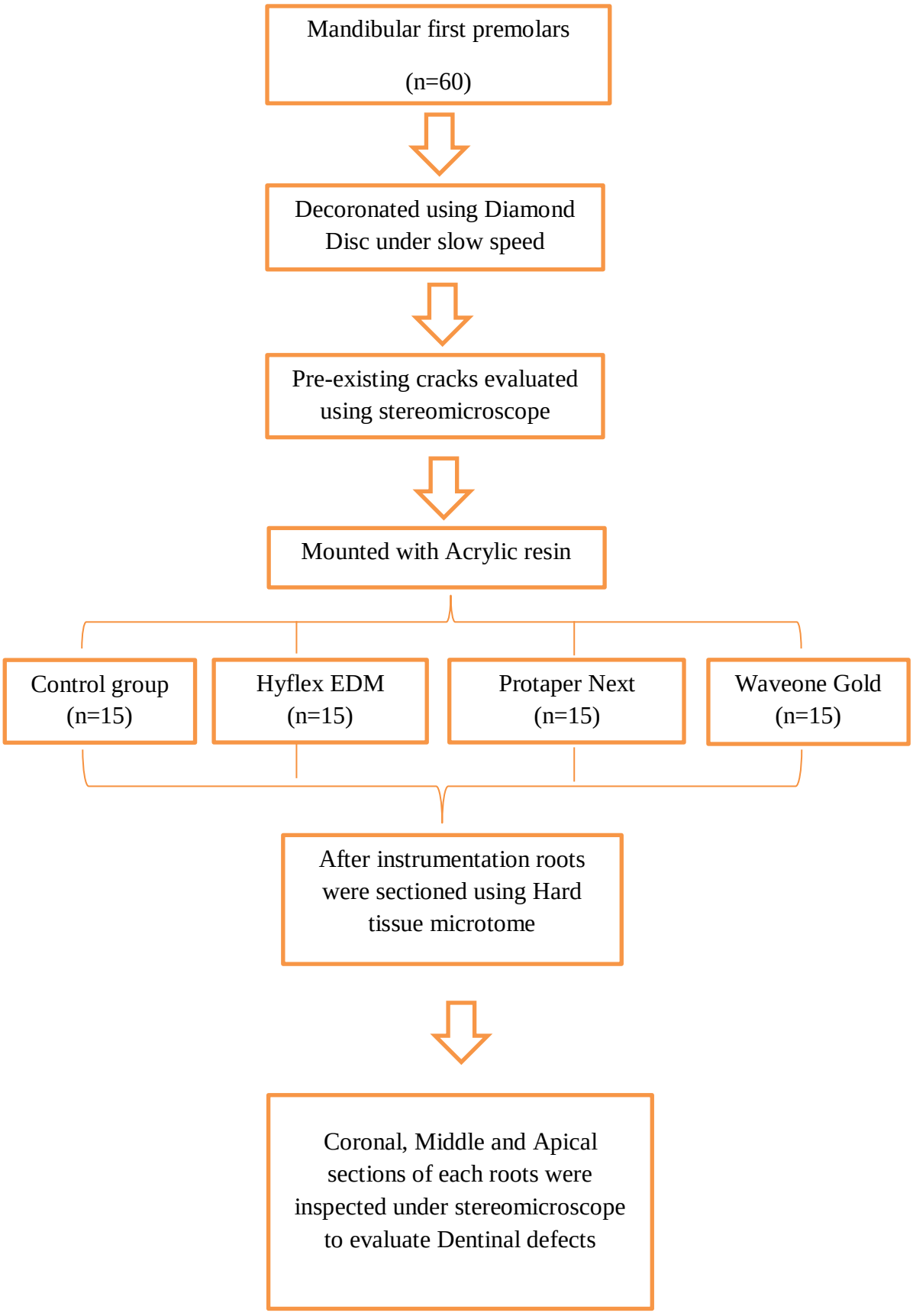


Figure 1. Schematic representation of Mounted roots.


Mandibular first premolars
(n=60)
Decoronated using Diamond Disc under slow speed
Pre-existing cracks evaluated using stereomicroscope
Mounted with Acrylic resin
Control group (n=15)
Hyflex EDM (n=15)
Protaper Next (n=15)
Waveone Gold (n=15)
After instrumentation roots were sectioned using Hard tissue microtome
Coronal, Middle and Apical sections of each roots were inspected under stereomicroscope to evaluate Dentinal defects

Canal preparation:

Control group (n=15) :

Control group was left unprepared.

Wave One Gold file group (n=15):

In this group the following sequence of Wave One Gold reciprocating files (Dentsply, Maillefer, Switzerland) were used to prepare the canals with Xsmart plus motors and 6:1 reducing handpiece. With an estimated working length and in the presence of a viscous chelator, size #10 file was inserted and simply worked within any region of the canal until it was completely loose. After that Proglider was inserted to the working length according to the manufacturer's instructions. The primary 25/08 Wave One Gold file was used with a gentle apically pressure to allow this instrument to run 2, 3, 4, mm inward with a brushing motion to eliminate the interferences.

Protaper Next group (n=15):

With an estimated working length and in the presence of a viscous chelator, size #10 file was inserted and simply worked within any region of the canal until it was completely loose. After that Proglider was inserted to the working length according to the manufacturer's instructions. The root canals were enlarged using the instruments X1 (17/0.04) and X2 (25/0.06) in sequence in a continuous rotary movement until the WL was reached, and all the canals were instrumented on the buccolingual and mesiodistal extensions. The motor used was a Xsmart plus with 300 rpm and 2Ncm of torque.

Hyflex EDM group (n=15):-

In this group the following sequence of Hyflex EDM files were used to prepare the canals with Xsmart plus motors and 6:1 reducing handpiece. With an estimated working length and in the presence of a viscous chelator, size #10 file was inserted and simply worked within any region of the canal until it was completely loose. Hyflex EDM orifice opener is used to enlarge the orifice and after that Hyflex EDM glidepath file was inserted to the working length according to the manufacturer's instructions. Hyflex EDM one file (25/~) was used to shape the canal to full working length, The HyFlex EDM files were used in a gentle in-and-out motion with a rotational speed of 500 rpm and 2.5 Ncm torque.

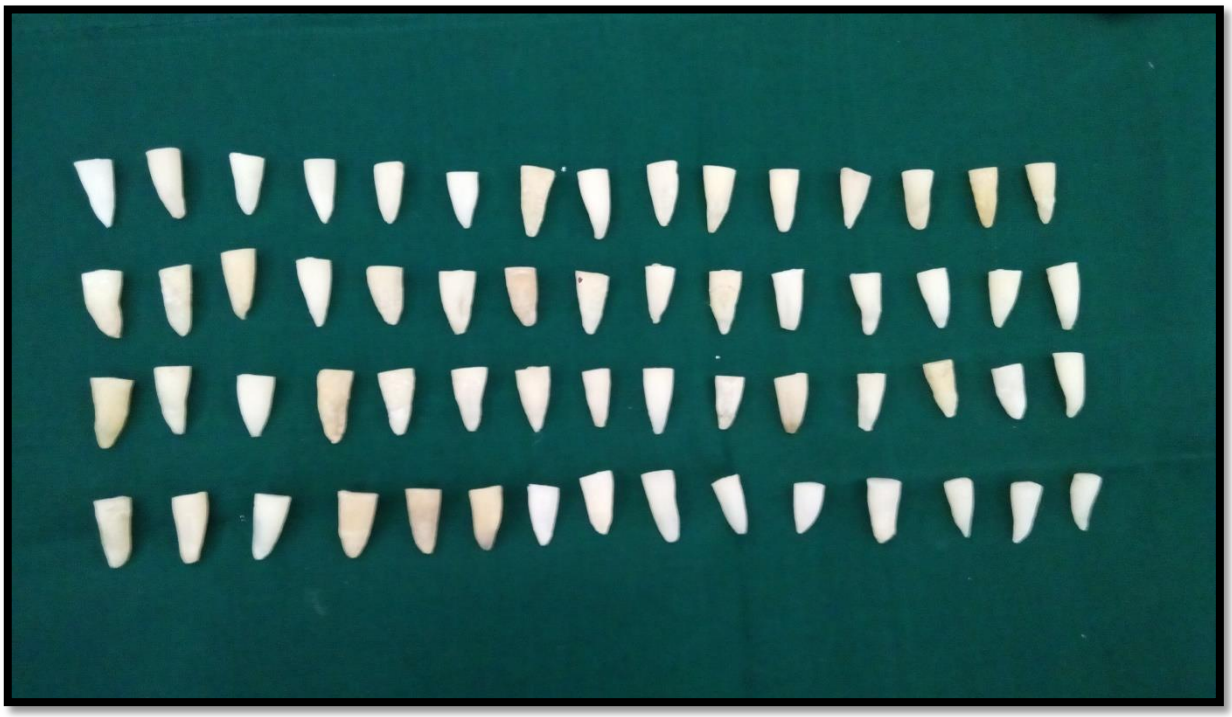


Figure 2. Sectioned specimens

Figure 3. Stereomicroscope

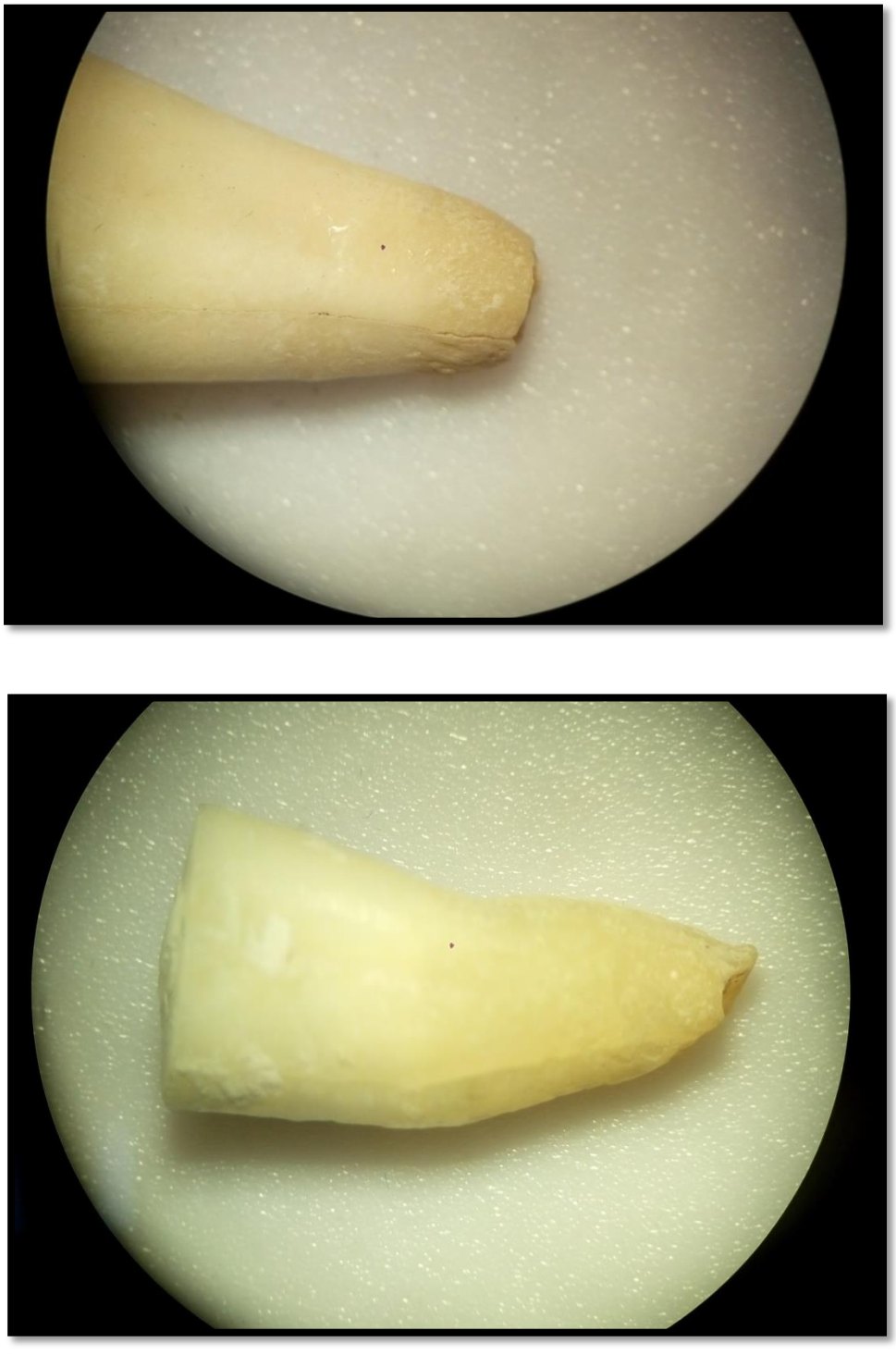


Figure 4. Pre-existing cracks

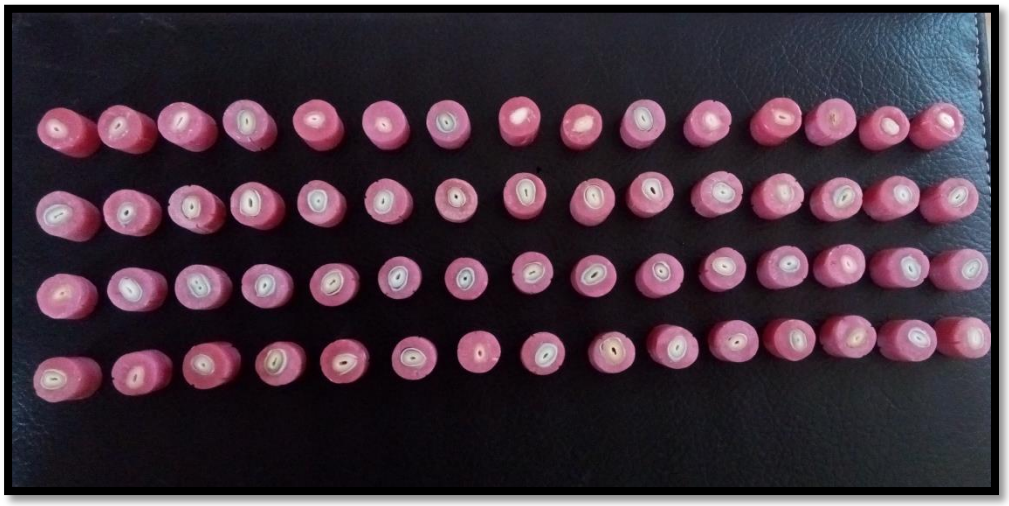


Figure 5. Mounted specimens

Figure 6. X Smart plus.

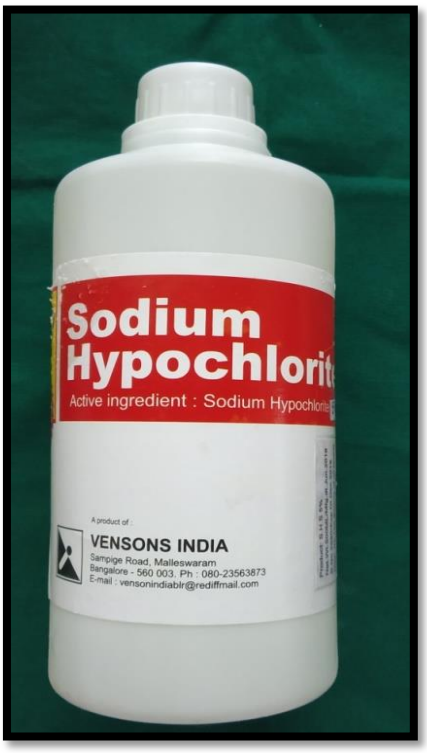


Figure 7. 5.25% Sodium Hypochlorite.

Figure 8. 17% Ethylene diamine Tetra acetic acid (EDTA).

Figure 9. Sectioning using Hard Tissue Microtome.

Each specimen was checked for the presence of dentinal defects (microcracks). **‘‘NO DEFECT’’** was defined as root dentin devoid of any craze lines or microcracks either at the external surface of the root or at the internal surface of the root canal wall. **‘‘DEFECT’’** was defined if any lines, microcracks, or fractures were present in root dentin. A total of 45 sections were examined in each group.

Results were expressed as the number and percentage of defected roots in each group. A chi-square test was performed to compare the appearance of defected roots between the experimental groups by using the SPSS/PC version 15 (SPSS Inc, Chicago, IL).The level of significance was set at p value < 0.05.

Figure 10. Stereomicroscope images for Control group.

Figure 11. Stereomicroscope images for Hyflex EDM group.

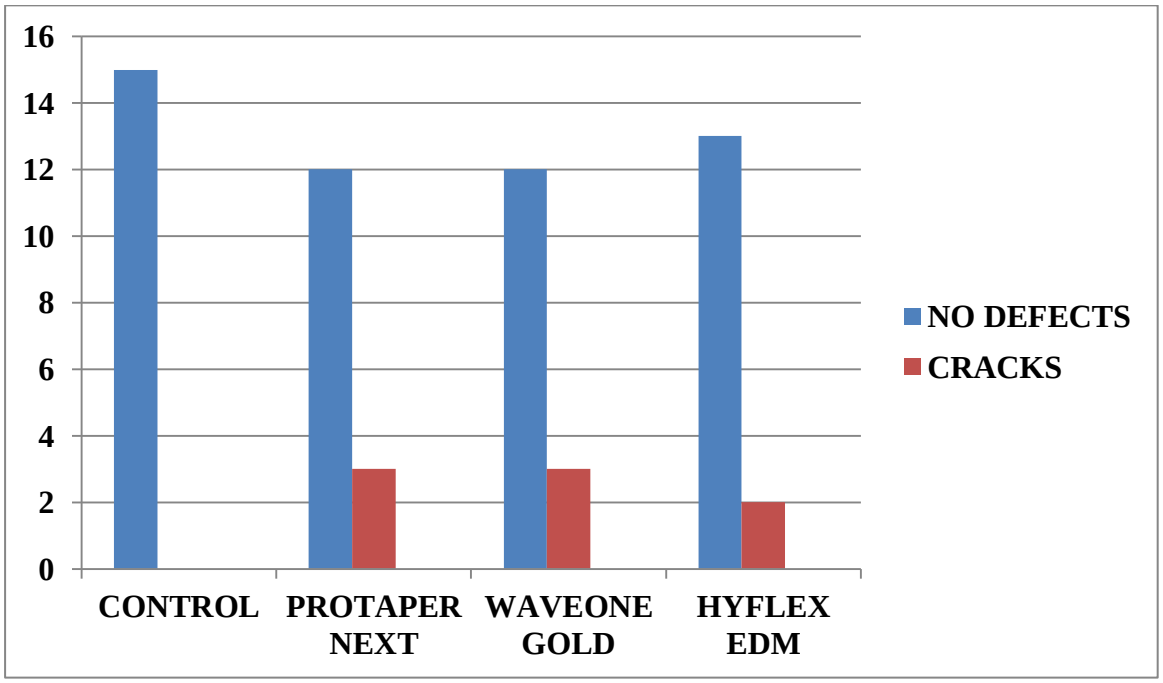
Figure 12. Stereomicroscope images for Waveone Gold Group.

Figure 13. Stereomicroscope images for Protaper Next.

CORONAL THIRD

CORONAL	CONTROL GROUP	PROTAPER NEXT	WAVEONE GOLD	HYFLEX EDM	TOTAL	*P* VALUE
NO DEFECT	15 (100%)	12 (80%)	12 (80%)	13 (87%)	52 (86%)	0.326
DEFECT	0 (0%)	3 (20%)	3 (20%)	2 (13%)	8 (14%)	

Table.1 Pearson chi square test for Coronal third region.

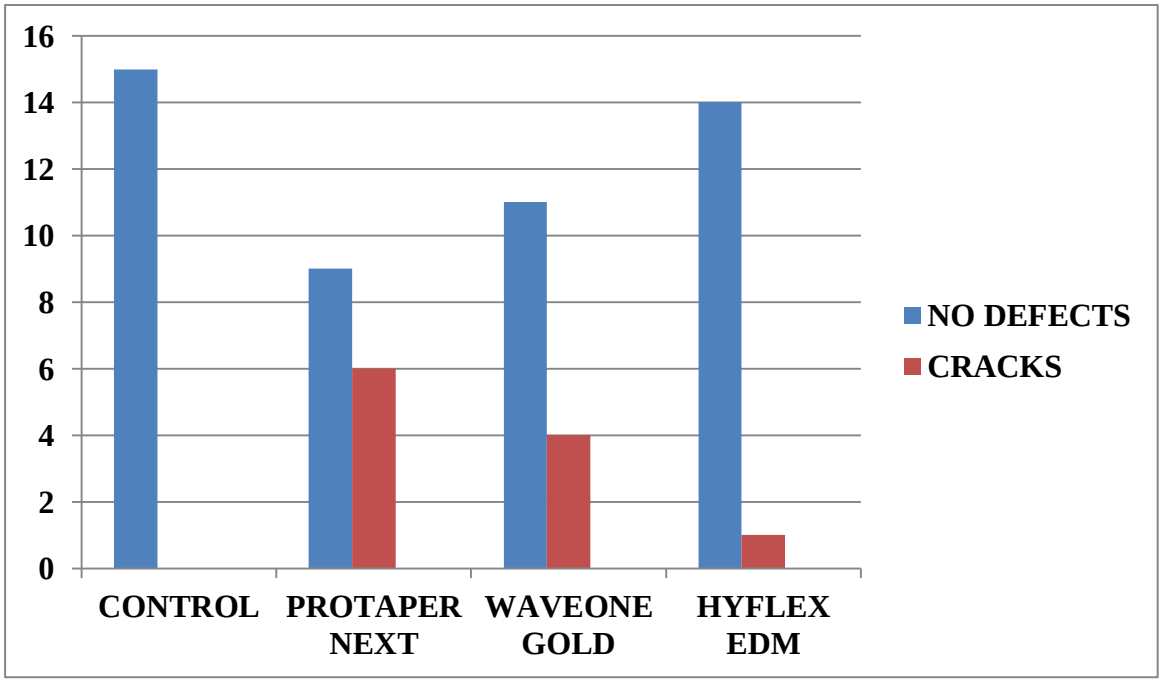


Bar diagram 1. Coronal third region.

MIDDLE THIRD

MIDDLE	CONTROL GROUP	PROTAPER NEXT	WAVEONE GOLD	HYFLEX EDM	TOTAL	*P* VALUE
NO DEFECT	15 (100%)	9 (60%)	11 (73%)	14 (93%)	49 (82%)	**0.017**
DEFECT	0 (0%)	6 (40%)	4 (27%)	1 (7%)	11 (18%)	

Table.2 Pearson chi square test for middle third region.

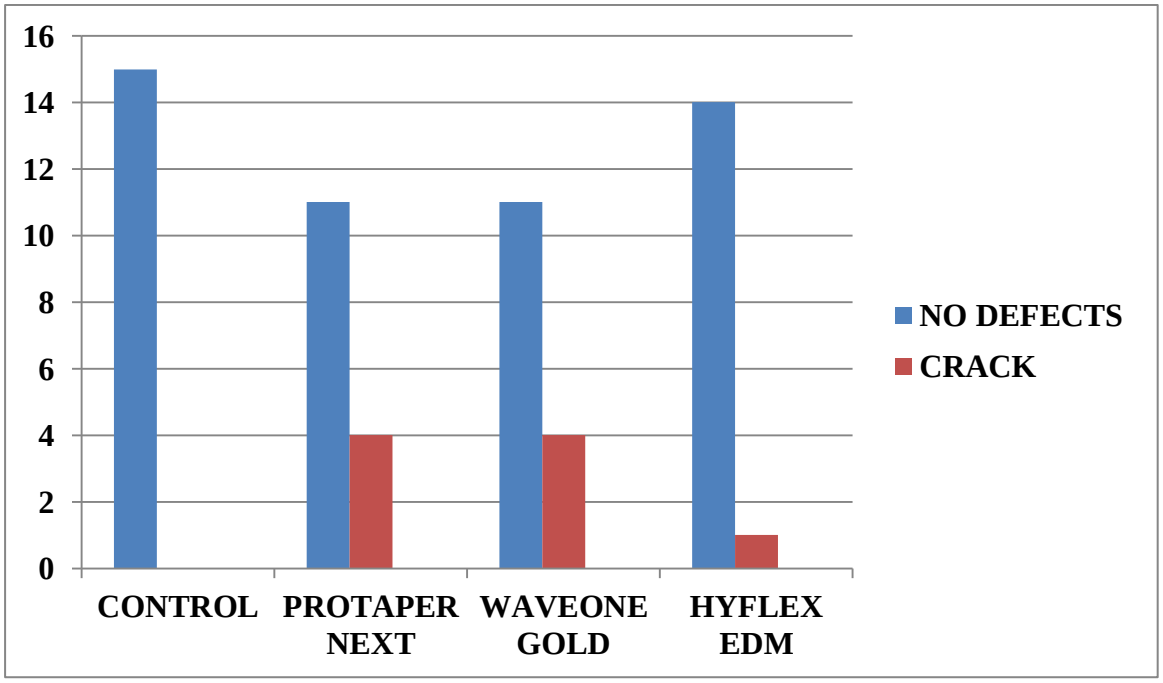


Bar diagram 2. Middle third region.

APICAL THIRD

APICAL	CONTROL GROUP	PROTAPER NEXT	WAVEONE GOLD	HYFLEX EDM	TOTAL	*P* VALUE
NO DEFECT	15 (100%)	11 (73%)	11 (73%)	14 (93%)	51 (85%)	**0.083**
DEFECT	0 (0%)	4 (27%)	4 (27%)	1 (7%)	9 (15%)	

Table.3 Pearson chi square test for apical third region.

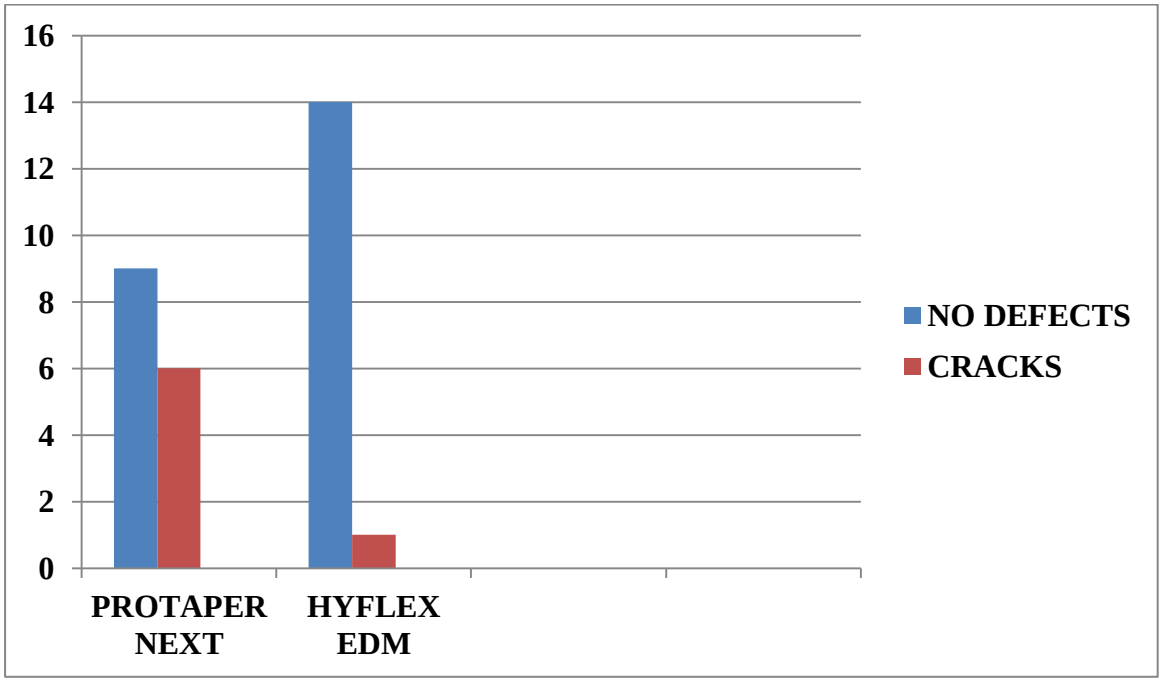


Bar diagram 3. Apical third region

MIDDLE THIRD (POST HOC TEST)

GROUPS	PROTAPER NEXT	HYFLEX EDM	P VALUE
NO DEFECT	9 (60%)	14 (93%)	.040
DEFECT	6 (40%)	1 (7%)	

Table.4 Post hoc test for middle third region.



Bar diagram 4.Post hoc test for middle third region.

The results of the present study showed that there was no statistically significant difference in coronal third region among all the three experimental groups.

There was statistically significant difference in the middle third region among the experimental groups. Post hoc test showed that there was significant difference between Protaper Next and Hyflex EDM group. But there was no significant difference between Waveone Gold and Hyflex EDM group.

In apical third region, there was no significant difference among all the three experimental groups.

Based on the mean values, Hyflex EDM performed better when compared with Protaper Next and Waveone Gold.

Traditionally, root canal preparation was carried out using stainless steel endodontic files manipulated by hand. In recent years, advances in rotary nickel titanium instruments have led to new designs and techniques of root canal preparation. But the major drawback associated with rotary nickel instrumentation is the incidence of dentinal defects which further leads to vertical root fracture (VRF). Another problem with nickel titanium instrument is instrument separation. Cyclic fatigue and torsional fatigue are the main causative factors for instrument separation.

To overcome the instrument separation and to improve the flexibility of Ni-Ti rotary instruments, manufacturers have been taking efforts to make Ni-Ti files of superior mechanical properties by using various cross sectional designs, surface treatment and different manufacturing processes. Till date, the incidence of dentinal defects associated with rotary NiTi instruments manufactured using different techniques have been reported in several studies.

When NiTi rotary instruments are used, a rotational force is applied to the root canal walls. Thus, they can create microcracks or craze lines in the root dentin. The extent of such a defect formation may be related to the tip design, cross-section geometry, constant or progressive taper type, constant or variable pitch and flute form. [18]

The stresses generated from inside the root canal are transmitted through the root to the surface where they might overcome the bonds holding the dentine together.[2]

Fracture occurs when the tensile stress in the canal wall exceeds the ultimate tensile strength of dentine.[49]

Hence, the present study aimed to evaluate the incidence of dentinal defects after root canal preparation using various nickel titanium instruments such as Hyflex EDM, Waveone Gold and Protaper Next.

In the present study, there is no statistically significant difference among the three groups in coronal and apical third region. Based on the mean values, Hyflex EDM showed least number of cracks than Protaper Next and Waveone Gold in the apical third region.

Results of this study showed that in the middle third region there is statistically significant difference between Hyflex EDM and Protaper Next. Hyflex EDM showed least number of cracks than Protaper Next. Although there is no statistically significant difference, Hyflex EDM showed least number of cracks than Waveone Gold.

In the present study, the least number of cracks associated with Hyflex EDM in the apical third region could be attributed to the flexibility of the nickel titanium instruments achieved from heat treatment. Eventhough all the three file systems are heat treated, the greater flexibility of Hyflex EDM is probably due to the synergistic effect of controlled memory wire and electric discharge machining process.[43]

Hyflex EDM showed significantly least number of cracks than Protaper Next in middle third region in the present study. This might be due to the variable taper of the Hyflex EDM file.[43] Eventhough all the three files are variable tapered, Protaper Next showed higher number of cracks than Hyflex EDM. This could be attributed to the lesser taper of Protaper Next instruments compared with Hyflex EDM. This result is in accordance with Adorno et al, who found that cracks were mostly initiated with smaller instruments rather than larger ones.[50]

Several studies reported that continuous rotary instruments produced more cracks than reciprocating instruments.[19,28,31] But in the present study, although there is no statistically significant difference, Hyflex EDM (Continuous rotary) showed least number of cracks when compared to Waveone Gold (Reciprocating) in middle and apical third region. This might be due to the fact the alloy from which the instrument is manufactured was an important factor in determining the damaging potential of single-file instruments rather than the motion of instrumentation.[23]

Yoldas et al stated that cross sectional geometry of the files could be a contributing factor in dentinal crack formation.[18] The off-centered rectangular design of Protaper Next and offset parallelogram shaped cross section of Waveone Gold instruments minimizes the contact between file and dentin which reduces stress thereby reducing the dentinal defects.[16,24,46] Despite these advantages of Protaper Next and Waveone Gold, Hyflex EDM showed least number of cracks in the present study. This showed that the alloy type, flexibility achieved from heat treatment and manufacturing process plays a major role in reducing the occurrence of dentinal defects than cross sectional geometry of the instruments.

Creating a glidepath provides several advantages such as preserving original canal anatomy, lower incidence of canal aberrations, less post-operative pain, lower incidence of separation of Ni-Ti rotary instruments and less instrument binding in the canal. The possibility of dentinal defects might be increased due to the excessive instrument binding and maximum contact between file and dentin. Hence in the present study, glidepath was used in all the three file systems according to the manufacturer's instructions.[33]

In the present study, Proglider was used to create glidepath in Waveone Gold group and Protaper Next group. Hyflex EDM glidepath was used in Hyflex EDM group. The least number of cracks associated with Hyflex EDM files in the middle third region can be attributed to the Hyflex EDM glidepath files. Similar to Hyflex EDM shaping files, glidepath files also manufactured using EDM process with controlled memory wire technology.[8]

It should be noted that in the present study, root canal instrumentation was performed 1mm short of the apical foramen, because the incidence of apical root cracks could be related to different instrumentation lengths. [27] In the current experiment, the roots were surrounded with an impression material to mimic the bony socket that might change the force distribution around the tooth when external forces were used. However, the clinical situation is more complex because of the presence of periodontal ligament that could further influence the distribution of forces.[13]

The most susceptible roots to fracture are those with narrow mesiodistal diameter compared with the buccolingual dimension as in maxillary premolars, mesial roots of mandibular molars and mandibular incisors.[51] In the present study, mandibular first premolars with straight canals were chosen and Hyflex EDM showed least number of cracks in middle third region than Protaper Next and Waveone Gold when compared with the other two regions. So, further studies are needed to evaluate the dentinal defects caused by Hyflex EDM in most susceptible roots to fracture such as roots with narrow mesiodistal diameter and curved canals.

SUMMARY

Sixty single rooted mandibular first premolars with straight canals were instrumented with Hyflex EDM, Protaper Next and Waveone Gold. After instrumentation, specimens were sectioned using hard tissue microtome and inspected under stereomicroscope to evaluate the incidence of dentinal defects after root canal instrumentation.

The findings of the present study is summarized as follows :-

- There was no statistically significant difference seen in coronal third and apical third region among the three groups.
- There was a significant difference seen in middle third region between Hyflex EDM and Protaper Next. Hyflex EDM showed least number of cracks.
- Although there was no statistically significant difference between Hyflex EDM and Waveone Gold, Hyflex EDM showed least number of cracks when compared with Waveone Gold in the middle third region.

CONCLUSION

Within the limitations of the present study, Hyflex EDM files manufactured using Electric Discharge Machining (EDM) process showed considerably good results compared to Protaper Next and Waveone Gold. Prudent selection of file system for instrumentation is of utmost importance for long term endodontic success.

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